

The Chaetognath Fauna off Peru in 1941¹

ROBERT BIERI²

EL NIÑO and the "Callao painter" of the Peruvian Coast have attained a classic stature in the annals of oceanography. The catastrophic effect of this phenomenon on the marine life of Peru is well known. The less devastating El Aguaje (literally strong current or rising tide) is not as notorious, but is nevertheless of considerable interest because it is a more general phenomenon, occurring off California, west Africa, and elsewhere.

Following the terminology of Sverdrup, Johnson, and Fleming (1942), El Niño is used in this paper to designate the intrusion south along the Peru coast of warm water less saline than the general surface water of the Peru current. In years of unusually heavy penetration of this water to the south the rainfall on the normally dry Peruvian coast is very great. El Aguaje refers to the intrusion to the coast of warm, relatively more saline water of oceanic origin from the west. This is frequently accompanied by minor red tides but does not bring heavy rainfall as does El Niño.

Such phenomena are not only of great economic importance due to the destruction of marine life, but also are of considerable scientific interest because they transport pelagic communities great distances from their normal ranges. Despite this, the precise effects of such occurrences on the quality and quantity of the local fauna are very poorly known.

The following discussion describes in some detail the distribution of 15 species of Chaetognatha in the surface water of the Peru coastal current in 1941, in the hope that it will serve as a basis for comparison with future work in the region and will allow a better evaluation

of the effects of these disturbances on the local fauna.

ACKNOWLEDGMENTS

It is a pleasure to thank Dr. Thomas E. Bowman of the United States National Museum for bringing the existence of the 1941 samples to the attention of the author and for his help in collecting data concerning the net tows. The samples were examined at the National Museum and the use of its facilities and equipment is gratefully acknowledged. Thanks are also due the Scripps Institution of Oceanography for the use of its facilities in examining the 1952 Shellback Expedition samples. Preparation of the manuscript for publication and examination of the National Museum material was partially supported by a Rockefeller Foundation Grant (RF 54087) to Lamont Geological Observatory, Columbia University.

PREVIOUS WORK

Our meager knowledge of the Chaetognatha in the southeast Pacific comes from a report by Baldasseroni (1915) who listed three species, *Sagitta enflata*, *S. lyra*, and *S. serratodentata* from a single station off Chile. The reports of Grey (1931) and Rose (1953) give some idea of the fauna far to the west in the central south Pacific.

The physical characteristics of the region are known chiefly from papers by Schott (1931), Gunther (1935), and a review of these and other data by Sverdrup, *et al.* (1942). Schweigger (1940) describes some of the physical and biological features present off the Peru coast in 1939. Sears (1954) gives an extensive list of literature dealing with the Peruvian coastal region. Fleming (1940), Schaefer (1954), Bowman (1955), Juhl (1955),

¹ Contribution from the Lamont Geological Observatory, No. 243, Biology Program 8. Manuscript received April 23, 1956.

² Lamont Geological Observatory, Columbia University, Palisades, New York.

Wilson and Shimada (1955), and Wooster and Jennings (1955) discuss various aspects of the hydrography and biology of the eastern tropical Pacific.

Several collections of zooplankton have been made in the vicinity of Peru—among them the Albatross, Dana, Discovery, and Carnegie collections—but analyses of the chaetognaths from these have not been published. During the course of a United States fisheries mission to Peru in 1941, Mr. Milton J. Lobell collected 25 plankton samples between Callao and the Gulf of Guayaquil in the period May 6 to 9 (Fig. 1). These samples form the basis of this report.

Recently zooplankton collections have been made off Peru by Scripps Institution in 1952 and 1955, and by the California Division of Fish and Game and the Bingham Oceanographic Laboratories in 1953 (Posner, 1954). The results of the plankton investigations of these institutions are not yet published, but the chaetognaths from the collections of the Scripps Shellback Expedition in 1952 (240 samples), and of the California Department of Fish and Game Longline Expedition in

1953 (26 samples), have been examined by the author. Part of the extensive 1952 material, in preparation for publication, is compared with the 1941 collection.

METHODS

The 1941 samples, preserved in dilute formalin, were collected with a one-half meter net made of bobbnet. The exact mesh of the bobbnet is not known, but judging from the size of the specimens caught it appears that the mesh was within the range of one-half to three-quarters of a millimeter. All of the tows were made at the surface and were of five minutes duration. Because of the uncertainty of the mesh size and the unknown speed of towing, no attempt has been made to estimate the volume of water filtered by the net. Instead the total number of specimens of each species collected in the tow is reported.

The author has found the following papers helpful in identifying the chaetognath species: Michael (1911), Ritter-Zahony (1911), Tokioka (1939 and 1940), Daken and Colefax (1940), Thomson (1947), and Fraser (1952). The nomenclature of Furnestin (1953), has been used for part of the *S. serratodentata* group.

RESULTS

Fifteen species of Chaetognatha were found in the surface waters off the Peruvian coast in 1941. Eight, or more than one-half of these, indicate warmer water present in May 1941 than in August 1952. Of the eight species, five, *Sagitta bedoti*, *Sagitta californica*, *Sagitta ferox*, *Sagitta neglecta*, and *Sagitta tenuis*, invaded the Peru coastal waters from the north. Three species, *Krohnitta pacifica*, *Sagitta regularis*, and *Sagitta robusta* penetrated the coastal waters from the west or the north. The remaining seven species, *Pterosagitta draco*, *Sagitta enflata*, *Sagitta hexaptera*, *Sagitta lyra*, *Sagitta minima*, *Sagitta pacifica*, and *Sagitta* sp., probably would show marked differences between May 1941 and August 1952 if it were possible

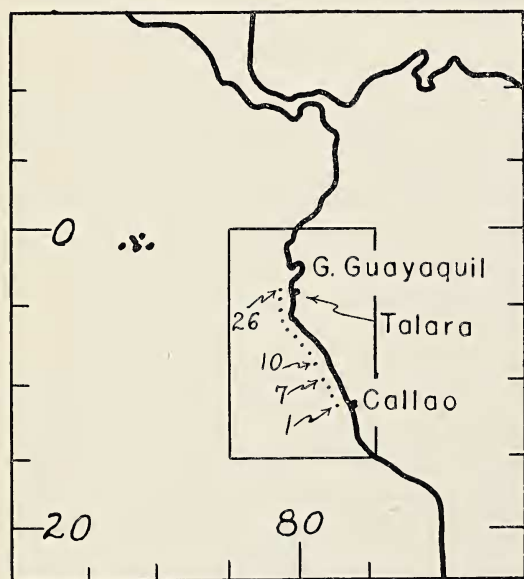


FIG. 1. Location of 1941 plankton samples. Every other station shown. Sample from station 9 not included in this report.

to compare their relative abundances or absolute concentrations.

In Figure 2 the total number of chaetognaths found at each station is shown. At no station were chaetognaths absent, but at the southernmost station only a single specimen was taken. The data are highly variable and no general trend is evident. The day tows averaged four times as many chaetognaths as the night tows but because of the great variability in abundance this is not regarded as significant.

In Figure 3 the number of species found at each station is shown. Although the data are highly variable, a general decrease in the number of species at the southern stations is apparent. This is due to a lack of equatorial and central oceanic species at the southern stations.

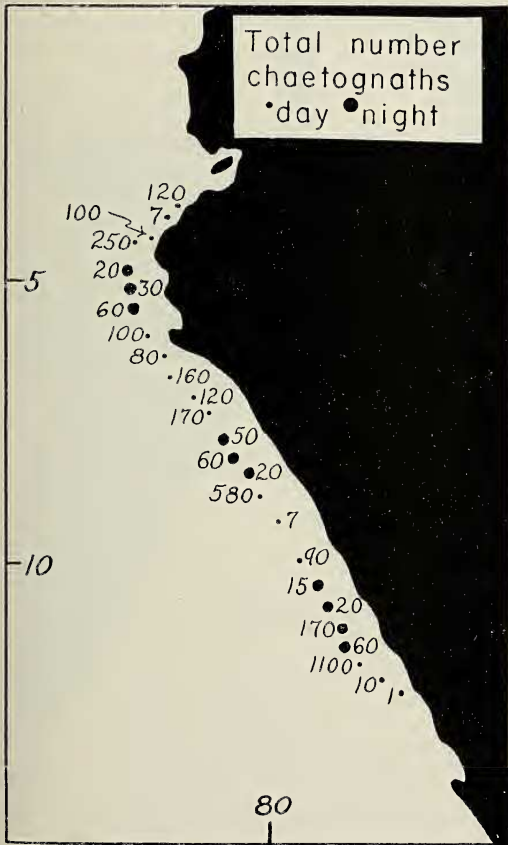


FIG. 2. Number of chaetognaths taken at each station in May 1941.



FIG. 3. Number of chaetognath species found at each station in 1941.

Pterosagitta draco (Fig. 4),* occurred at all but four stations. This species, which can be characterized as a warm water inhabitant, is found throughout the Pacific except off the California and Korean coasts between roughly 40 degrees north and 40 degrees south (Bieri, unpublished data). As might be expected, it does not show any marked discontinuities in the Peru region, but does appear to decrease in abundance at the southern stations.

Krohnitta pacifica (Fig. 5) occurred at nine nearly consecutive stations. This species was absent from the inshore stations off Peru during August, 1952 (Shellback Expedition).

* In Figures 4-13, the numbers refer to the number of specimens of the chaetognath species being discussed which were taken in a five-minute surface tow, using a one-half meter net.

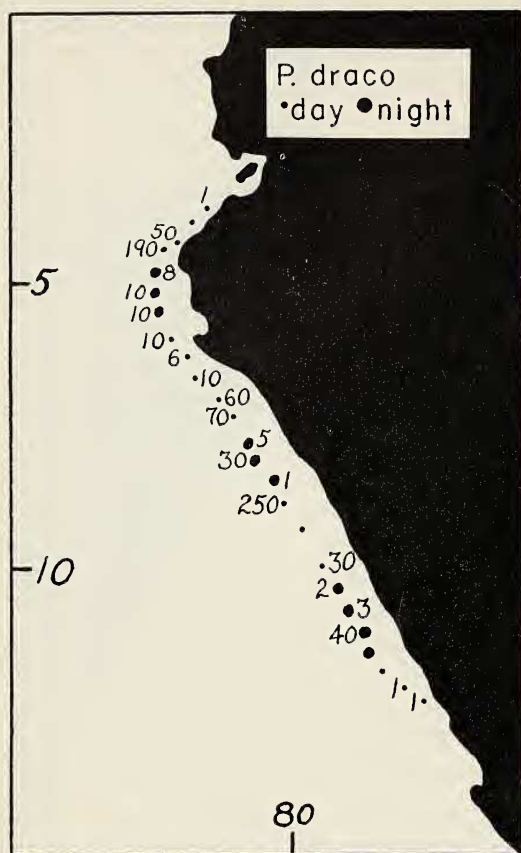


FIG. 4. Occurrence of *Pterosagitta draco* off Peru in 1941. (Number per five-minute surface tow, one-half meter net.)

Whether or not this difference is a seasonal one can only be shown by repeated short interval sampling over a period of several years. It can be said, however, that the presence of the species closer to the coast in 1941 could be due to greater penetration of south Pacific central water from the west towards the coast in 1941 or greater southern penetration of equatorial water from the north.

Sagitta bedoti occurred sporadically in low numbers at 14 stations (Fig. 6) with the greatest numbers in the north. It was found in the nearshore region of Peru in 1952 but appears to have penetrated further south in 1941.

Immature specimens of what appeared to be *Sagitta californica* were found at four stations (a single specimen at stations 14, 18, and 9

and three specimens at station 17). This species is widespread in the Pacific, occurring from roughly 38 degrees north to 38 degrees south; however, it is missing or extremely rare in the equatorial region (about 5 degrees north to 5 degrees south) and is missing from most of the California current. It is not common near shore except during unusual conditions such as reported by Michael in 1913. It was present at only one station off Peru in 1952 (14°01'S, 81°47'W) but was common north of the equator at that time. It appears most likely that the specimens in 1941 came from the north although the possibility of an intrusion from the southwest of Peru cannot be definitely ruled out.

Sagitta enflata (Fig. 7) occurred at all but three of the 1941 stations. Its distribution in



FIG. 5. 1941 distribution of *Krohnitta pacifica* compared to 1952. Crosses with hatchure—present 1952, without hatchure—absent 1952.



FIG. 6. Distribution of *Sagitta bedoti* in 1941 and 1952. Crosses with hatchure—present 1952, without hatchure—absent 1952.

the Pacific is very similar to that of *P. draco* and does not indicate any major change. A large form of *S. enflata* maturing at 20 mm. or longer was taken at stations 2, 3, 4, 19, and 21. In 1952 this form was also recorded from the Peru current.

The distribution of *Sagitta ferox* (Fig. 8), except for its occurrence at station three, is very similar to that of *K. pacifica* and suggests a common origin of the two local populations. In 1952 it was missing south of the equator except for four stations west of 100 degrees west longitude. Thus it would appear that this species could only have come from the north.

Sagitta hexaptera (Fig. 9) was found in small numbers at 12 stations in 1941. Its distribu-

tion throughout the Pacific is similar to but somewhat more widespread than that of *P. draco* and *S. enflata*; however, it is not usually found as close to shore as *S. enflata* nor is it as abundant. This together with its possibly different vertical distribution probably explains its patchy appearance in the 1941 collections.

Single specimens of *Sagitta lyra* were taken at stations 22, 17, and 14 and ten specimens at station 23. This species is found throughout the Pacific from approximately 45 degrees north to about 45 degrees south latitude. It is usually absent from very warm surface waters, inhabiting the cooler waters below. Its occurrence at the above stations therefore might

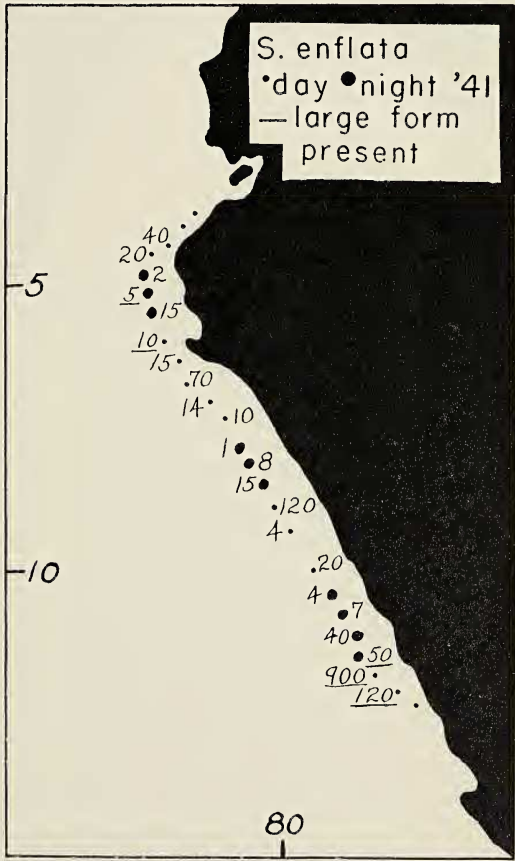


FIG. 7. Occurrence of *Sagitta enflata* off Peru in 1941. A large form of *S. enflata* maturing at a length of 20 mm. or greater occurred at the stations with underlined concentrations.

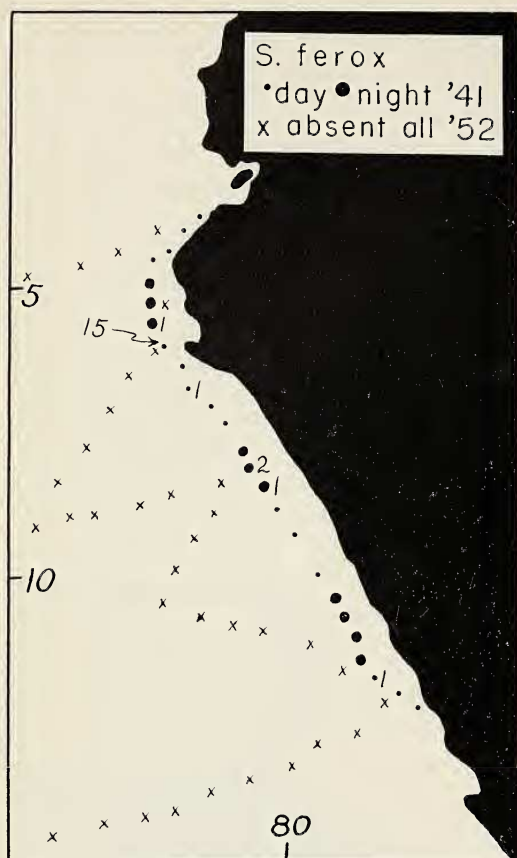


FIG. 8. Distribution of *Sagitta ferox* in 1941 and 1952. Crosses are 1952 stations. *S. ferox* was absent from all 1952 stations.



FIG. 9. Occurrence of *Sagitta hexaptera* off Peru in 1941.

seem somewhat anomalous since it occurs together with equatorial species. Its distribution together with that of *S. minima* indicates complex conditions between stations 14 and 23.

Single specimens of *Sagitta minima* were taken at stations 22 and 19 while five specimens were taken at station 18 and three specimens at 16. This species has a widespread but irregular distribution in the Pacific and is most abundant in cool offshore waters. It occurred sporadically off Peru in 1952.

A single specimen of *Sagitta neglecta* was taken at station 17. In 1952 *S. neglecta* did not occur south of about three degrees south latitude; thus the present record indicates some southward penetration of equatorial water.

Sagitta regularis (Fig. 10) had a distribution similar to *K. pacifica* and *S. ferox* in 1941 and occurred considerably inshore of its limits in 1952. It could have reached this position by intrusion of water from the north or west.

Sagitta robusta (Fig. 11) apparently was more common off Peru in 1941 than in 1952. Since this species is most abundant in warm waters, it indicates warmer water present off Peru in May 1941 than in August 1952.

The *Sagitta serratodentata* group is here split into two populations provisionally called *Sagitta pacifica* (Furnestin, 1953) and *Sagitta* sp. *S. pacifica* has a distribution similar to *P. draco*, *S. enflata*, and *S. hexaptera* and is found at nearly every station in 1941 (Fig. 12).

Sagitta sp. is apparently new to science and will be described in a future publication. It

has a distribution similar to *S. minima* but occurs somewhat deeper than that species. In 1952 it occurred at every station off Peru while in 1941 a single specimen was taken at station 7. Much of this difference is no doubt due to the fact that the 1952 net tows were oblique to about 300 meters, but more extensive sampling of the surface waters off Peru may show that *Sagitta* sp. was unusually scarce there in 1941. A specimen belonging to the *serratodentata* group was taken at station 13 and is for convenience called *S. serratodentata atlantica* since it most closely fits the description given by Thomson (1947). It is considered for the present to be a form of *S. pacifica* and part of that population.

Sagitta tenuis (Fig. 13) occurred at 12 sta-



FIG. 10. Distribution of *Sagitta regularis* in 1941 and 1952. Crosses with hatchure—present 1952, without hatchure—absent 1952.

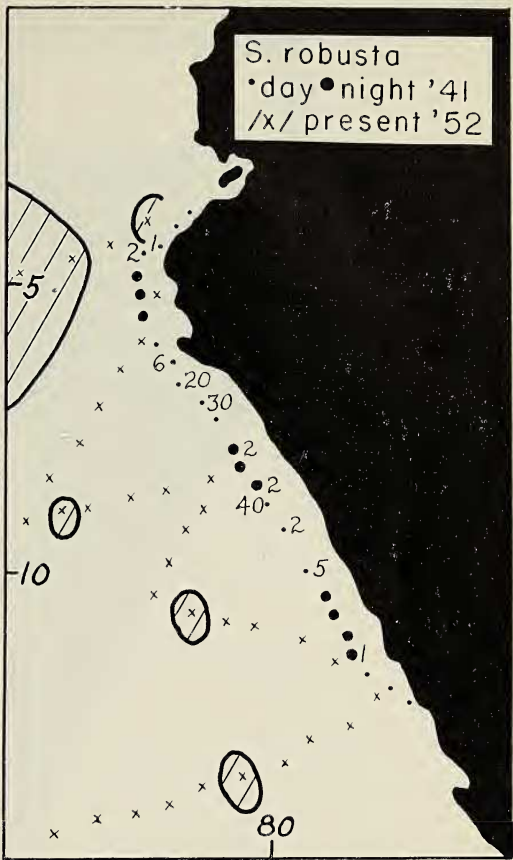


FIG. 11. Distribution of *Sagitta robusta* in 1941 and 1952. Crosses with hatchure—present 1952, without hatchure—absent 1952.

tions in 1941. The taxonomic status of this species has been in doubt for many years. Most workers (Faure, 1952; Fraser, 1952; Tokioka, 1955) have kept *S. tenuis* and *S. friderici* as separate species. The author also held this opinion for some time; however, in the 1941 Peru material a complete set of intergrades exists between *S. friderici* to the south and *S. tenuis* to the north. The same situation has been observed by the author in samples taken off Lower California except that there the *tenuis*-like form is to the south and the *friderici*-like form to the north. Michael (1911) called this species *Sagitta bipunctata*. In view of these intergrades, it would appear that *S. tenuis* and *S. friderici* are ecotypic variants of a single interbreeding population or species. Because

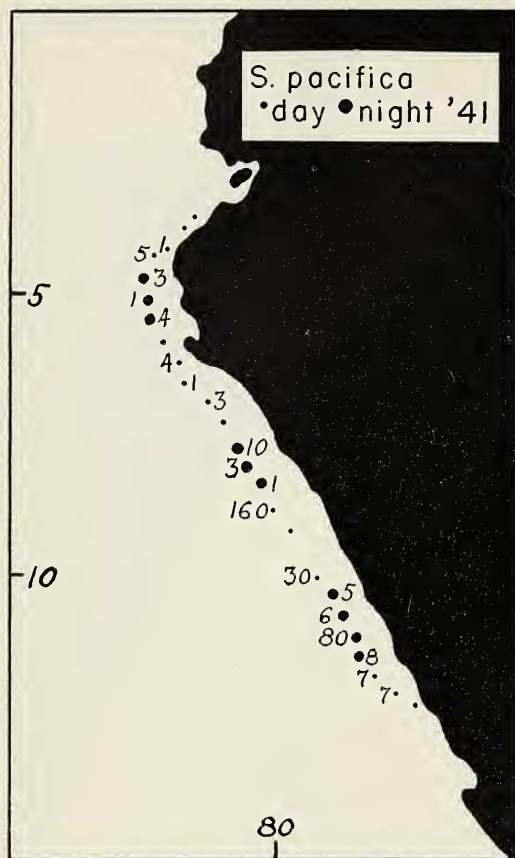


FIG. 12. Occurrence of *Sagitta pacifica* off Peru in 1941.

of the great variability of the species, it is the author's opinion that *S. setosa*, living in water of reduced salinity, is also a form of the species and is interbreeding with the population in the eastern Atlantic. However, until this hypothesis can be definitely established or disproved, it seems best to retain the name *S. tenuis* for the species. The correlation of the morphologic variations of this species with its physical environment and the untangling of the involved synonymy will be treated more extensively in a paper on the general biology of the species now in preparation.

In 1952 *S. tenuis* occurred at only three northern stations and was of the large *friderici*-like form. In 1941 this form was found to the south and the small *tenuis*-like form at the northern stations. Apparently in August of

1952 the *tenuis*-like form (warm water) did not extend south of the Gulf of Guayaquil while in 1941 it reached south to the coast of Peru.

CONCLUSION

Although the material available is not as extensive as might be desired, there is no doubt that the May 1941 distribution of chaetognaths off Peru was significantly different from the August 1952 distribution. The relationship of the 1941 and 1952 samples to El Niño and El Aguaje is shown in Figure 14.

The following hypothesis is advanced as an explanation of the data presented above in the hope that it will lead to more thorough and critical field and laboratory investigations to test its validity.

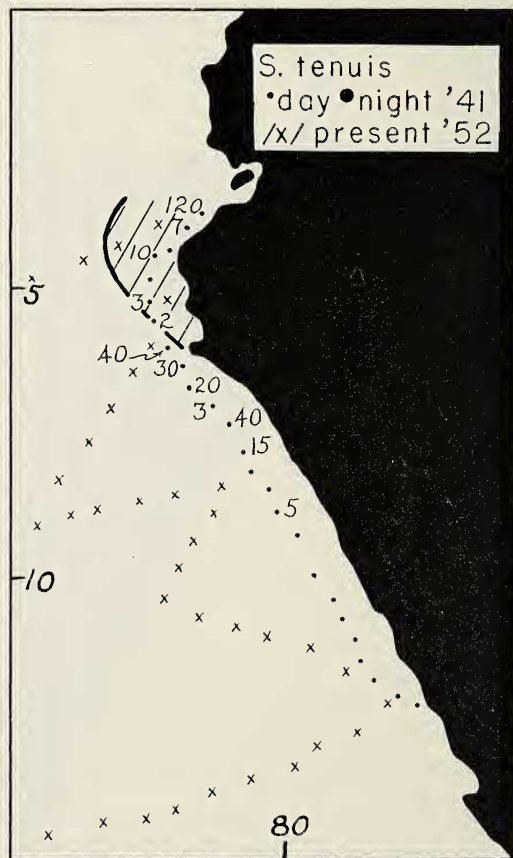


FIG. 13. Distribution of *Sagitta tenuis* off Peru in 1941 and 1952. Crosses with hatchure—present 1952, without hatchure—absent 1952.

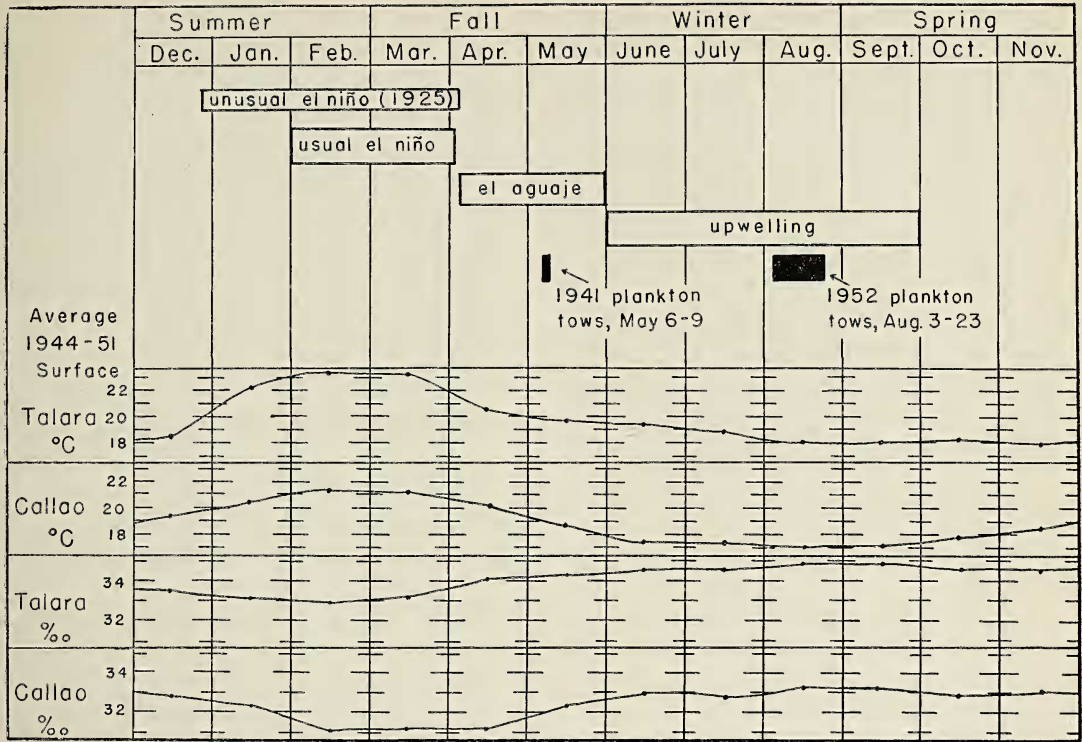


FIG. 14. The relationship of the 1941 and 1952 plankton samples to the physical environment off Peru. The extent in time of El Niño, El Aguaje, and upwelling are taken from Sverdup, Johnson, and Fleming, 1942. The average surface temperature in degrees centigrade and surface salinity in 0/00 are based on Coast and Geodetic Survey publications 280 and 281. The increase in temperature and concurrent decrease in salinity during the months of January through April are conspicuous.

The August 1952 samples, indicating cool water conditions, are probably more representative of the usual conditions off Peru than are the May 1941 samples because the Peru coast is characterized by relatively cool water (Fig. 14). El Niño was apparently above average strength in 1941 as indicated by the heavy rainfall that year (Sverdrup *et al.*, 1946; Sears, 1953). The chaetognath population in the surface water off Peru in May 1941 is thought to have been formed from individuals brought in from the west by El Aguaje and mixed with the remnants of a population brought down from the north by El Niño earlier in the year.

Sagitta pulchra, a common species in the Gulf of Panama, was not found in the 1941 samples. This species might occur off Peru at

the height of unusually strong penetration of water from the north.

REFERENCES

BALDASSERONI, V. 1915. Chetognati dalle pubblicazioni R. Istituto di studi superior di Firenze. IN *Raccolte planctoniche fatte dalla R. Nave "Liguria" nel viaggio di circonnavigazione del 1903-05*, 2(5): 85-118.

BOWMAN, T. E. 1955. A new copepod of the genus *Calanus* from the northeastern Pacific with notes on *Calanus tenuicornis* Dana. *Pacific Sci.* 9(4): 413-422.

DAKEN, W. J., and A. N. COLEFAX. 1940. The plankton of the Australian coastal waters off New South Wales. *Sydney Univ., Dept. Zool., Monog.* 1(1): 63-70.

FAURE, M. L. 1952. Contribution a l'étude morphologique et biologique de deux chae-

- tognathes des eaux Atlantiques du Maroc: *Sagitta friderici* Ritter-Zahony et *Sagitta bipunctata* Quoy et Gaimard. *Vie et Milieu, Bul. du Lab. Arago de l'Univ. de Paris, Actualités Sci. et Indus.* 3(1):25-43.
- FIEDLER, R. H., N. D. JARVIS, and M. J. LOBELL. 1943. *La pesca y las industrias pesqueras en el Peru*. Compañía Administradora del Guano. 371 pp. Lima.
- FLEMING, R. H. 1940. A contribution to the oceanography of the Central American region. *6th Pacific Sci. Cong. Proc.* 3: 167-175.
- FRASER, J. H. 1952. The Chaetognatha and other zooplankton of the Scottish area and their value as biological indicators of hydrological conditions. *Scottish Home Dept. Mar. Res., Pub.* 2. 52 pp.
- FURNESTIN, M. L. 1953. Contribution à l'étude morphologique, biologique et systematic de *Sagitta serrato-dentata* Krohn les eaux atlantiques du Maroc. *Inst. Océanog., Bul.* 50(1025). 39 pp.
- GREY, B. B. 1931. Chaetognatha from the Society Islands. *Roy. Soc. Queensland, Proc.* 42: 62-67.
- JUHL, R. 1955. Notes on the feeding habits of subsurface yellowfin and bigeye tunas of the eastern tropical Pacific ocean. *Calif. Fish and Game* 4(1): 99-101.
- MICHAEL, E. L. 1911. Classification and vertical distribution of the Chaetognatha of the San Diego region including redescrptions of some doubtful species of the group. *Calif. Univ., Pubs., Zool.* 8(3): 21-186.
- 1913. *Sagitta californica*, n. sp., from the San Diego Region including remarks on its variation and distribution. *Calif. Univ., Pubs., Zool.* 2(5): 89-126.
- POSNER, G. S. 1954. The Peru Current. *Sci. Amer.* 190(3): 66-71.
- RITTER-ZAHONY, R. 1911. Revision der Chätognathen. *Deutsche Südpolar Exped. 1901-03. Zool.* 5(1). 71 pp.
- ROSE, M. 1953. Quelques renseignements sur le plankton des Iles Tuamotu. *Natl. Mus. d'Hist. Nat., Bul.* 25, ser. 2(5): 456-462.
- SCHAEFER, M. B. 1954. Report on the investigations of the Inter-American Tropical Tuna Commission for the year 1953. *Inter-Amer. Trop. Tuna Comm., Ann. Rpt., 1953, App. A:* 18-50.
- SCHWEIGGER, E. H. 1940. Studies of the Peru coastal current with reference to the extraordinary summer of 1939. *6th Pacific Sci. Cong. Proc.* 3: 177-195.
- SEARS, M. 1954. Notes on the Peruvian coastal current. 1. An introduction to the ecology of Pisco Bay. *Deep Sea Res.* 1(3): 141-169.
- SVERDRUP, H. U., M. W. JOHNSON, and R. H. FLEMING. 1942. *The Oceans*. 1078 pp. Prentice-Hall, Inc., New York.
- THOMSON, J. M. 1947. The Chaetognatha of southeastern Australia. *Austral. Council Sci. & Indus. Res., Bul.* 222. 43 pp.
- TOKIOKA, T. 1939. Chaetognaths collected chiefly from the bays of Sagami and Suruga, with notes on the shape and structure of the seminal vesicle. *Rec. Oceanog. Works in Japan* 10(2): 123-150.
- 1940. The chaetognath fauna of the waters of Western Japan. *Rec. Oceanog. Works in Japan* 12(1). 22 pp.
- 1955. Notes on some chaetognaths from the Gulf of Mexico. *Mar. Sci. Gulf Carib., Bul.* 5(1): 52-65.
- U. S. COAST AND GEODETIC SURVEY. 1952. *Surface Water Temperatures at Tide Stations, Pacific Coast North and South America and Pacific Ocean Islands*. U. S. Dept. Com. Spec. Pub. 280. 59 pp.
- 1954. *Density of Sea Water at Tide Stations, Pacific Coast North and South America and Pacific Ocean Islands*. U. S. Dept. Com., Washington. 63 pp.
- WILSON, R. C., and B. M. SHIMADA. 1955. Tuna longlining results of a cruise to the eastern tropical Pacific Ocean. *Calif. Fish and Game* 41(1): 91-98.
- WOOSTER, W. S., and F. JENNINGS. 1955. Exploratory oceanographic observations in the eastern tropical Pacific, January to March, 1953. *Calif. Fish and Game* 41(1): 79-90.